Discriminating Between Severe and Non-Severe Storms

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Background

- Numerous relationships between total lightning and severe weather suggest that lightning data can be used to help assess the potential for severe weather.
  - **CG lightning within severe storms**
    - Polarity, multiplicity, and peak current (e.g., Biggar 2002 and Carey et al. 2003)
  - **Total lightning and severe weather**
    - Lightning “jumps” and “holes” (e.g., Browning 1964, Williams et al. 1999, Lang et al. 2004, Goodman et al. 2005, and Gatlin 2007)
  - **Severe vs. non-severe** (CG and IC relationships)
    - e.g., MacGorman and Morgenstern 1998, Carey and Rutledge 2003, and Montanya et al. 2007
- Our Hypothesis → “Total lightning data, used in conjunction with radar data, allow researchers and forecasters to gain a better understanding of thunderstorm morphology and its relation to severe weather.” (Steiger et al. 2007)

Important Considerations

- **GLM Mission Objectives**
  - Provide continuous full-disk total lightning data for storm warning and nowcasting
  - Provide early warning of tornadic activity
- **Thought Provoking Questions**
  - Is the NWS currently using current lightning data to best advantage when assessing severe weather events?
  - Is the NWS fully prepared to utilize the upcoming GLM data to aid in determining severe weather potential?

Research Objectives

- Develop algorithms and guidelines to determine whether a particular storm is likely to require a warning.
- Determine statistical relationships between radar-derived parameters and total lightning characteristics.
- Create guidance products that **best** utilize **existing** and **future** total lightning data (e.g., GOES-R GLM) in assessing storm severity.
- Develop for use in the NWS warning assessment process.

Probably more research than can be
expected from one Ph.D. Candidate

Research Objectives

- **Specifics of our plan**
  - LMA network in Sterling, VA will be major focus.
  - Also consider Northern Alabama and Kennedy Space Center to determine regional influences.
  - Synthesize findings from as many storms as possible.
  - Categorize storms according to type (i.e., isolated supercell, line, pulse, and non-severe).
  - Develop algorithms and applications that automate data set preparation and facilitate analyses of individual storms.
  - Evaluate proxy data and parameters to determine how to best incorporate the GLM data into the algorithms and database.

What is our Approach?

- Utilize the Warning Decision Support System – Integrated Information software (WDSS-II)
- Examine multiple data sources simultaneously
  - WDSS-II allows us to synthesize, manipulate, and display many types of data

WSR-88D

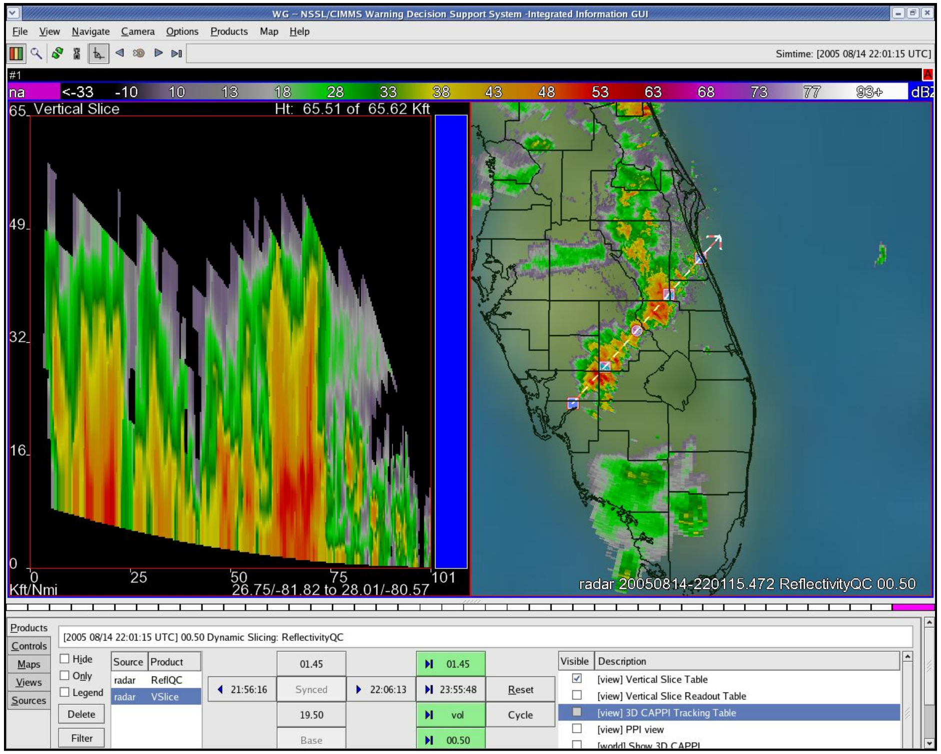
NLDN

IR Satellite

LDAR/LMA

RUC (20 km)

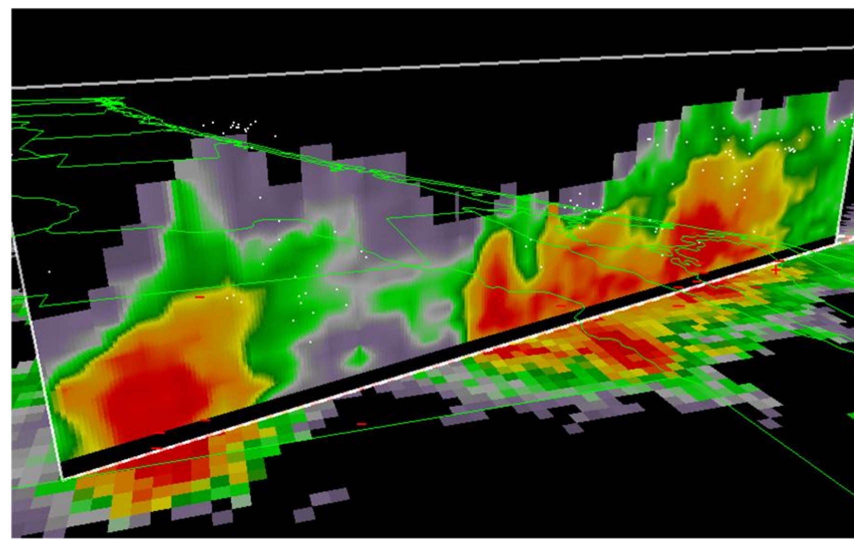
GLM proxy data



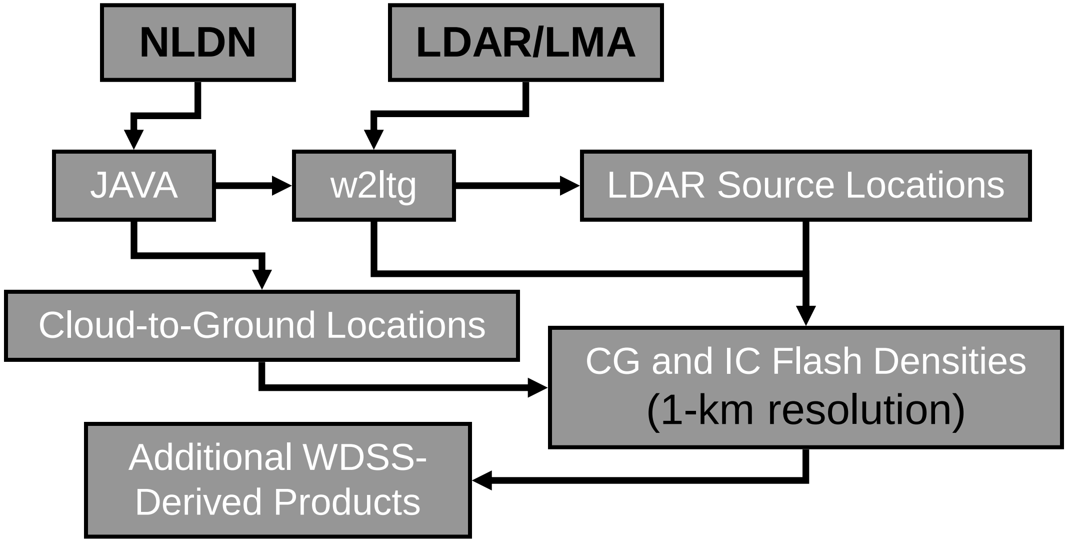
Processing Radar and RUC Data

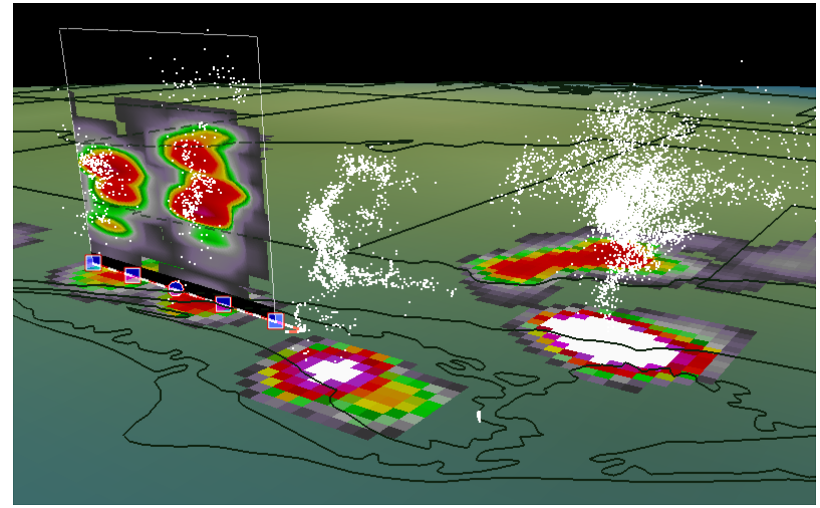
RUC (20 km)
→ Basic Parameters
→ Near-Storm Environment
→ Isotherm Levels
→ Moisture Parameters
→ Wind Profile
→ Stability Parameters
→ Severe Weather Indices

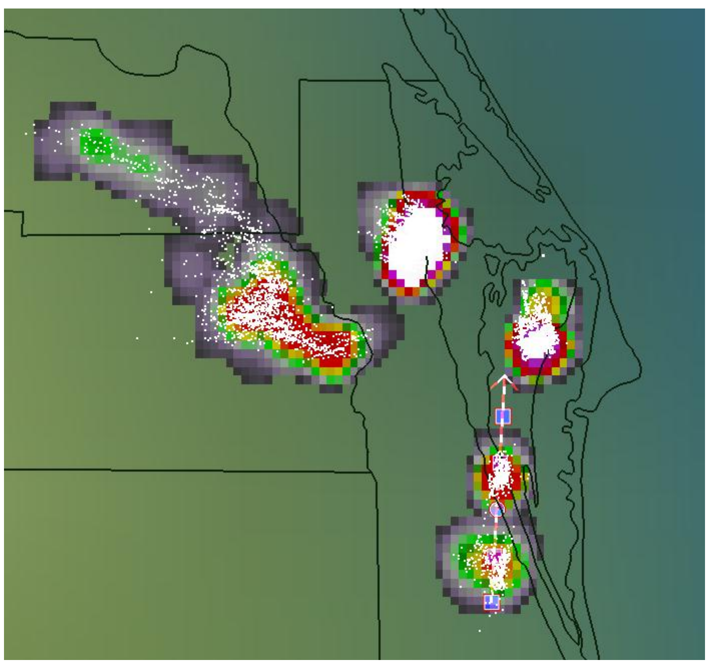
WSR-88D
→ Reflectivity
→ ReflectivityQC
→ ReflectivityQCComposite
→ Velocity
→ AzShear0-3km



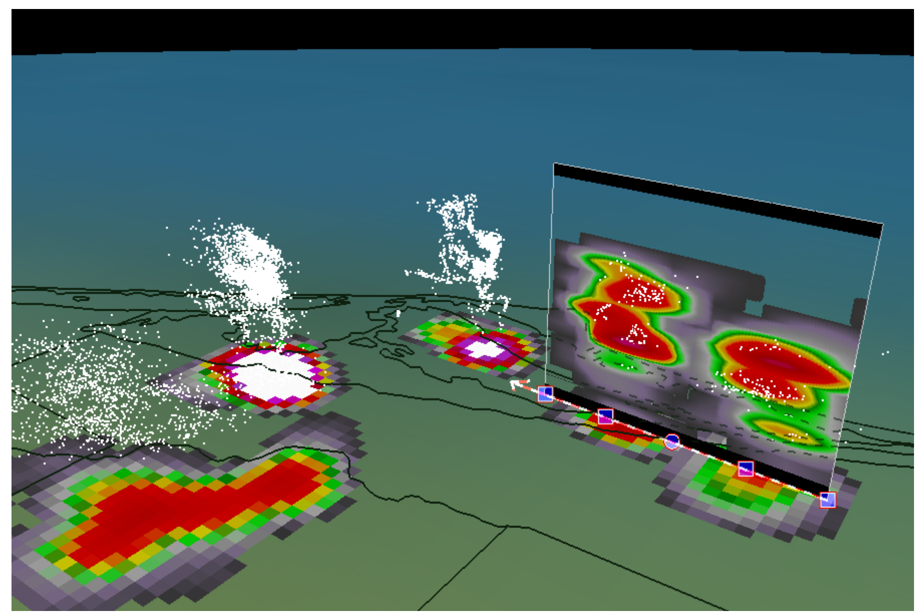
Processing Lightning Data





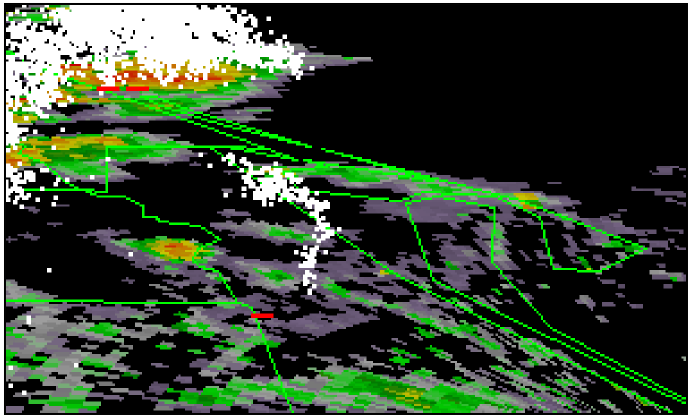


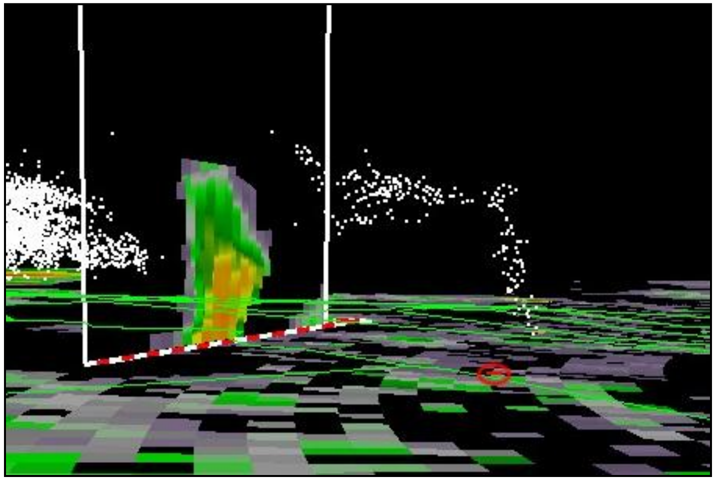
Dots: 1-min LDAR source locations;
Cross-Section: LDAR source density;
Plan-view: LDAR source density 8 km above ground level (AGL)



Course of Action

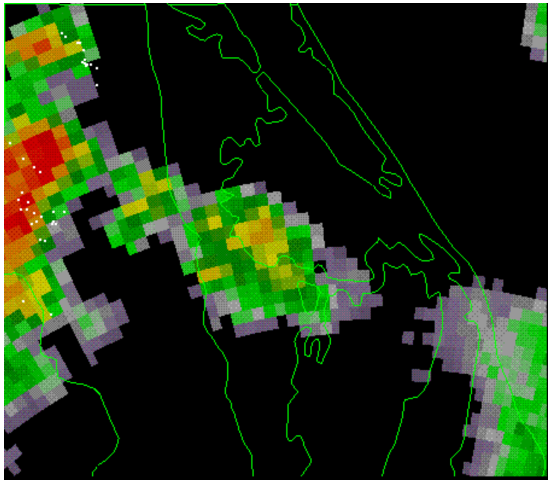
- Identify and track individual storm cells
  - Link cells with lightning
  - Relate radar and lightning parameters
  - Determine if isolated supercell, line, pulse, or non-severe storm
- Prepare storm database
  - Modify and automate procedures
  - Statistical analyses of parameters
  - Probabilistic determination of severity
- GOES-R GLM resolution
  - Exploiting both the spatial and temporal aspects

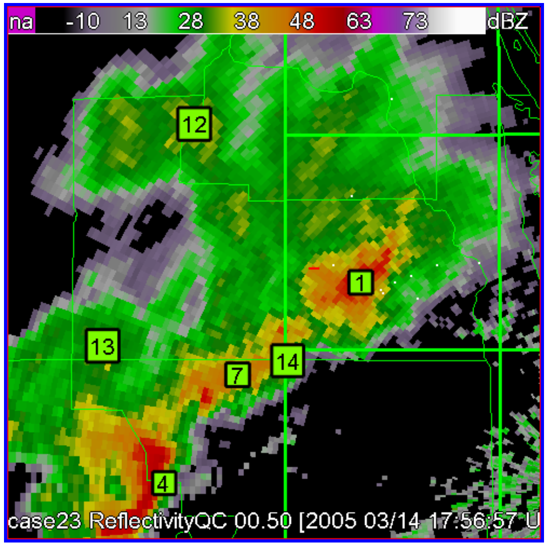




Identifying Cells: Early Approach

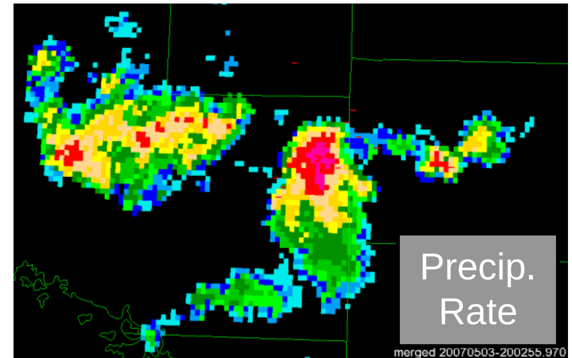
- Storm Cell Identification and Tracking (SCIT)
  - Intermittent tracking
  - Temporally dependent
  - Limited storm characteristics
- Common linking methods
  - Predefined radii
  - Visual inspection
  - Some combination
- Limitations of the approach
  - Achieving accuracy is time consuming
  - Necessitates case study mode

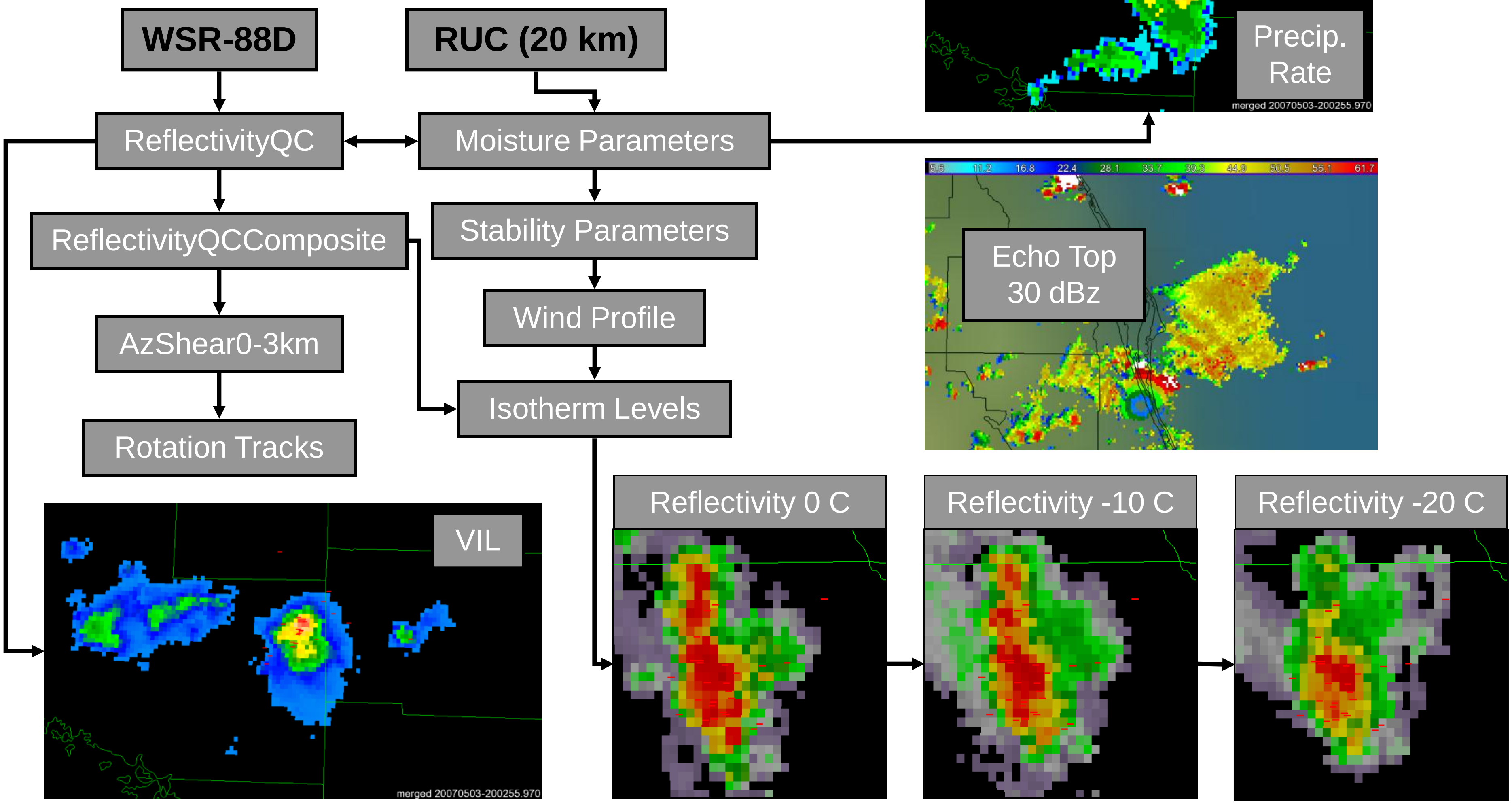




Identifying Cells: Our Approach

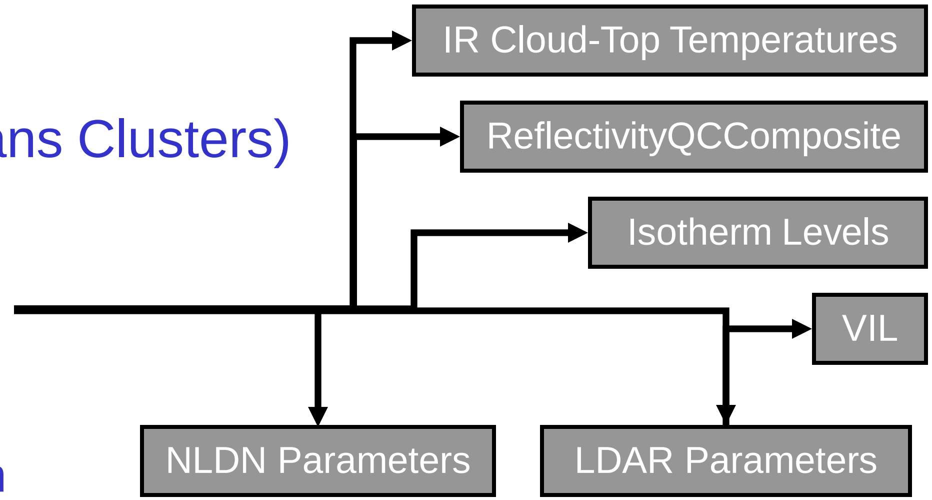
- WDSS-II Algorithms
  - Radar-RUC Merger (w2merger)

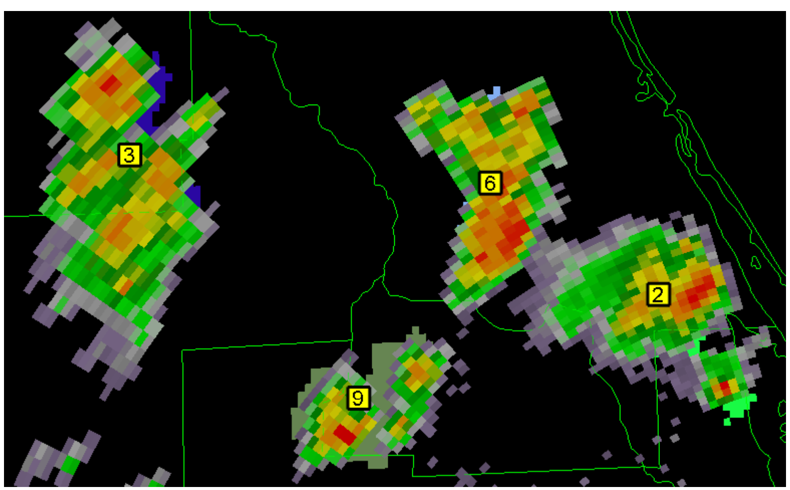




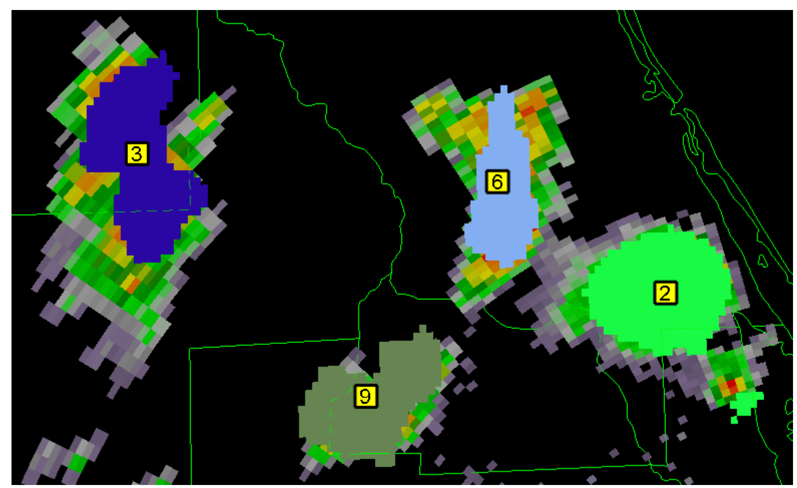
Identifying Cells: Our Approach

- WDSS-II Algorithms
  - w2segmotion (Creates K-Means Clusters)
    - Features as small as 10 km²
    - Utilize any gridded field e.g.,
    - Advection of features
    - Improved temporal resolution
    - Can create forecasts





Reflectivity (0.5° elevation scan)



K–Means clusters of ReflectivityQCComposite overlaid on Reflectivity (0.5°)

Linking Cells with Lightning

NLDN → Cloud-to-Ground Locations

LDAR/LMA → LDAR Source Locations

WDSS algorithm (w2ltg)

Flash Densities:

NLDN-CG (1×1 km)

LDAR/LMA-IC (1×1×1 km)

(1×1 km on 1 km levels sfc-20km)

Additional WDSS-Derived Products

CG Flash Density

1 km

1 km

3D Lightning Density

LMA Layer Average

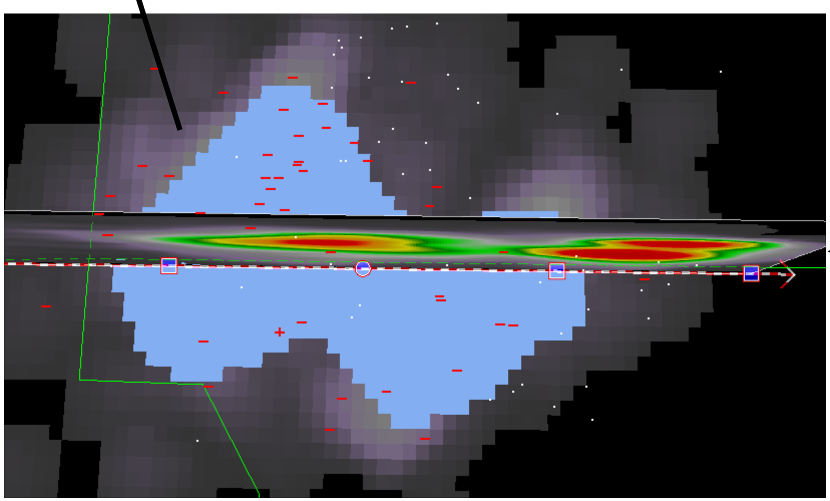
Height Max LMA

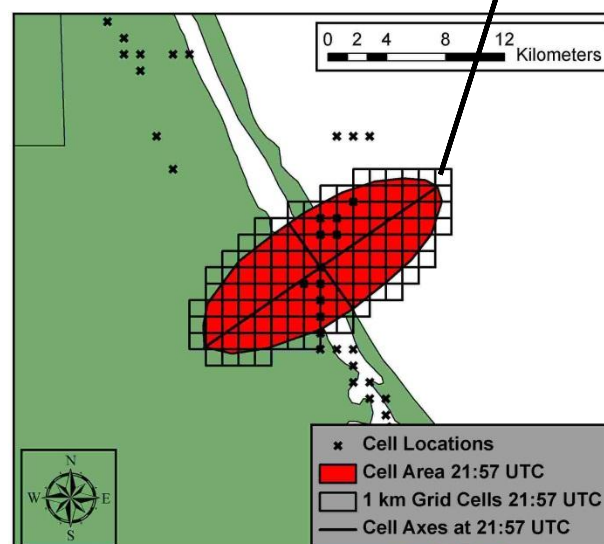
Max LMA

VILMA

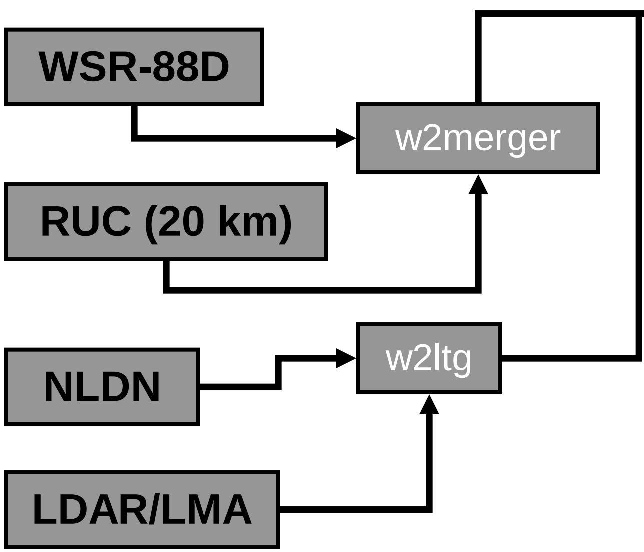
1 km

1 km





Linking Cells with Lightning



w2segmotion

<u>w2segmotion options</u>:

-T tracked Product Name

-d “min max incr”

-f cluster field(s)

-X cluster xml file

-w Model Wind Field Name

<u>xml cluster options</u>:

avg, standev, min, max, count;

time delta, decision tree, fuzzy logic, mathematical operations

<u>Standard Variables</u>:

Lat, Lon, LatRadius,

LonRadius, Orientation,

AspectRatio, Size, Speed,

MotionEast, MotionSouth

<u>Cluster Field(s)</u>:

MergedAzShear 0-3 km

EchoTop 18-30-50 dBz

ReflectivityBelowZero

Reflectivity_0C,-10C, -20C

PrecipTotal5min, 15min

PrecipRate

VIL

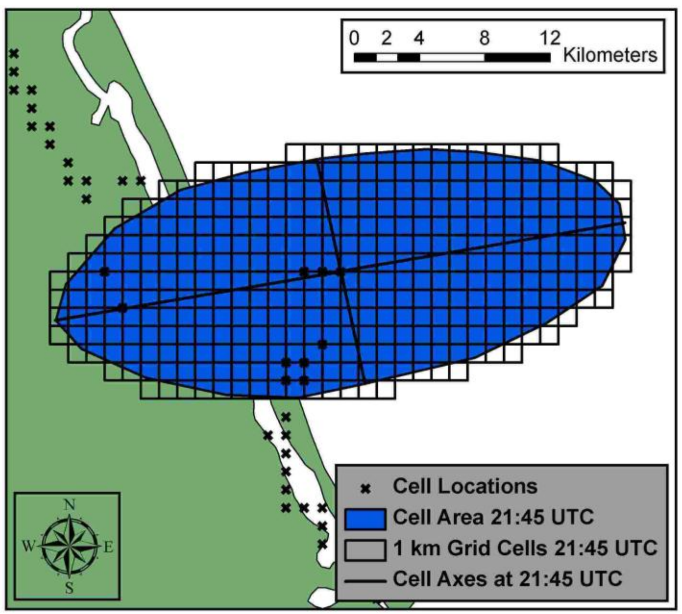
<u>NLDN</u>: LightningDensity

<u>LDAR/LMA</u> : MaxLMA,

LMALayerAverage

HtMaxLMA

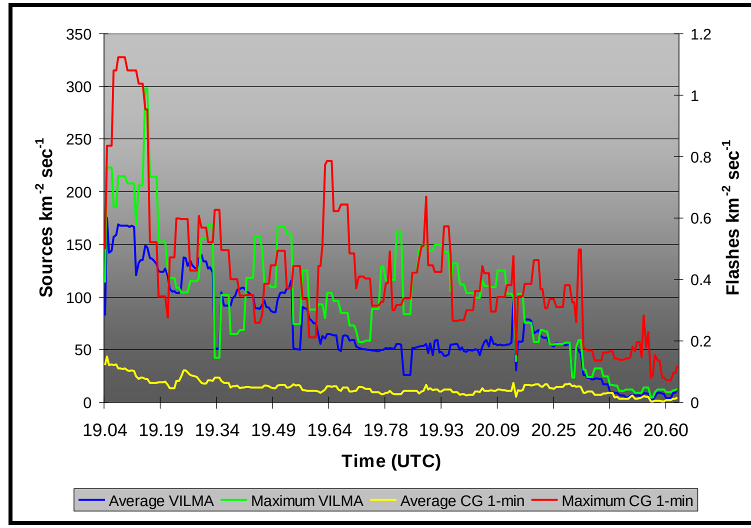
VILMA

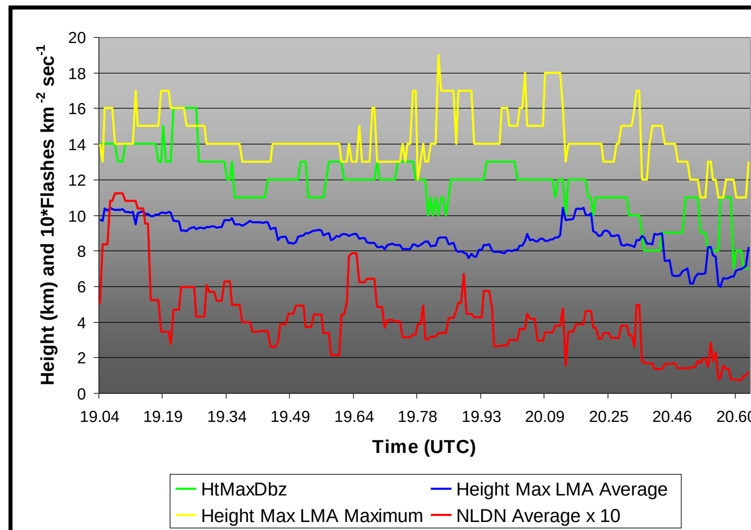


<u>Final Table</u>: Contains standard variables and those calculated for each cluster during every desired time period.

Lightning Parameters within Storms

- Higher order lightning parameters
  - **Within the moving cluster**
    - Maximum 1×1 km cell
    - Average of 1×1 km cells
  - **Over varying time periods**
    - Compute differences, trends, life-time statistics, etc.
  - **Describe lightning characteristics**
    - Aspect ratio of column
      - Evaluate storm life cycles
    - Lightning “jumps” at various levels
      - Sudden shifts in the vertical
    - Trends in space and time
      - Three-dimensional parameters





<u>14 August 2005</u>: **Top**: Lightning rates, **Bottom**: LDAR heights and CG flash rates.

NSSL Storm Type Identification

<u>w2segmotion</u>:

(With advanced features developed at NSSL)

<u>Decision Tree Considers</u>:

Size, speed, aspect ratio, low level shear, max VIL, MESH, mean reflectivity, and orientation.

<u>Decision Tree Determines</u>:

Isolated supercell, line, pulse, and non-severe storms

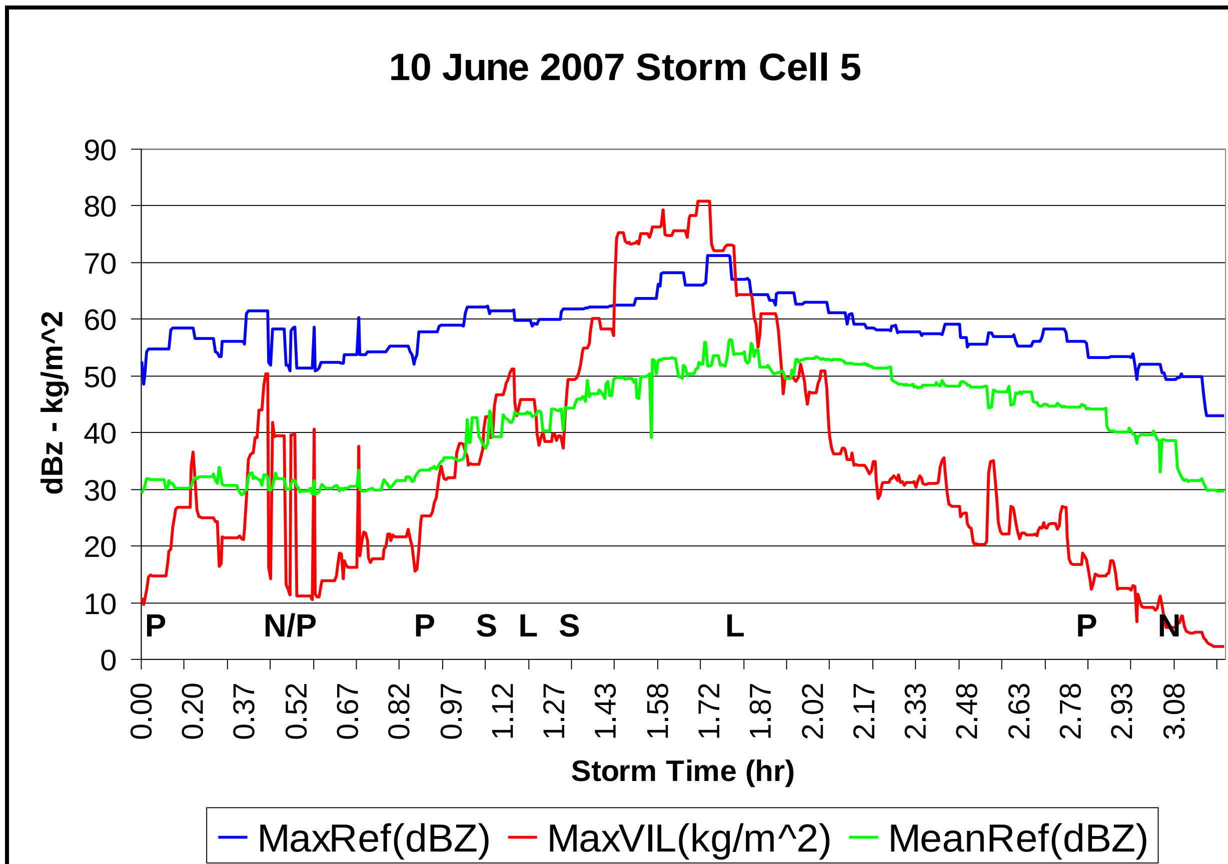
<u>w2segmotion options</u>:

-T ReflectivityQCComposite

-d “30 60 10”

-f “VIL, MESH, POSH, SHI,
Echo Top 18-30-50 dBz,
Low Level Shear”

-X StormTypeInput.xml



L = Line

P = Pulse

N = Not Severe

S = Isolated Supercell

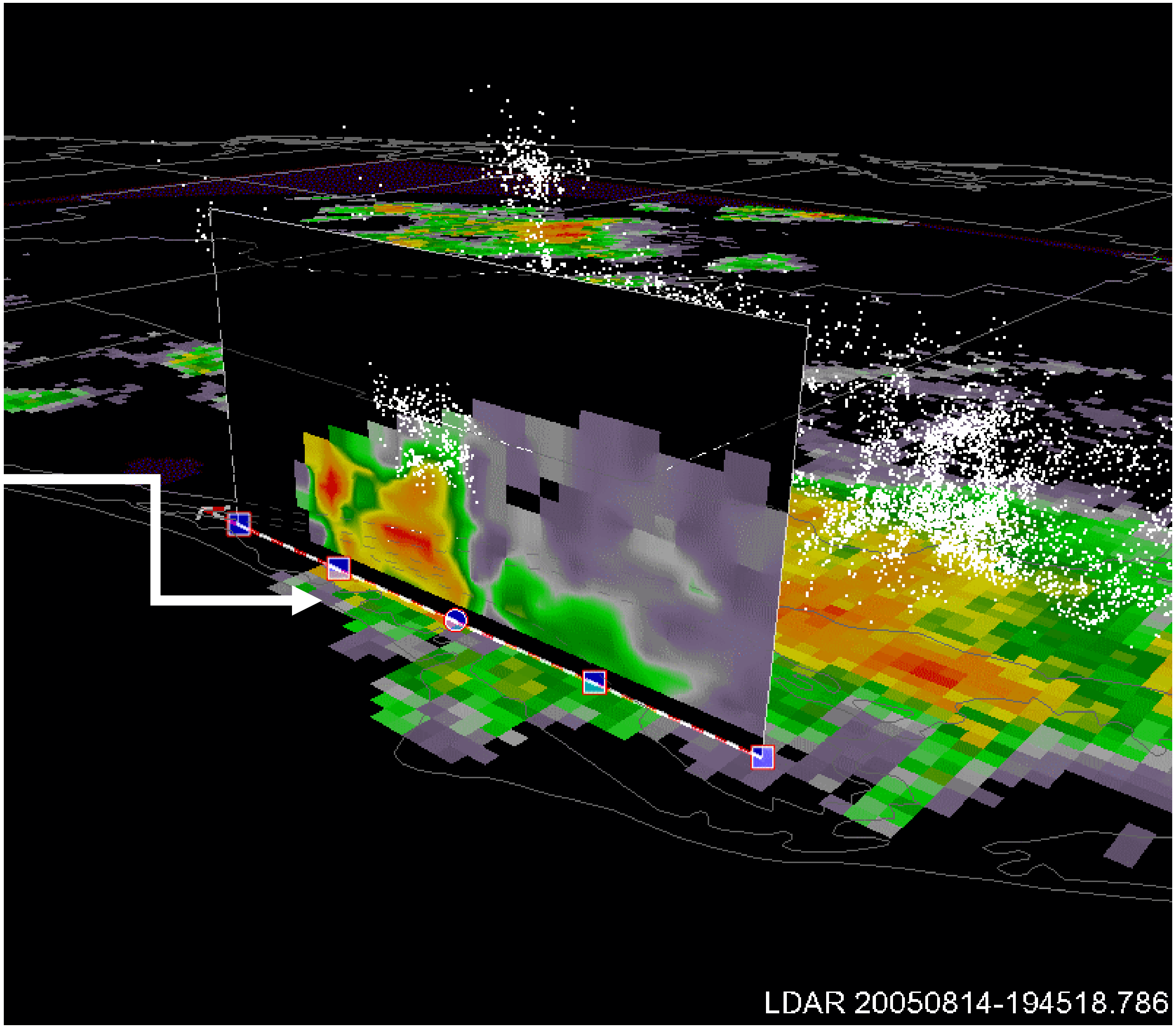
Examining Many Storms

- **Streamline database development and analysis**
  - Automate procedures from database creation through the visualization of individual storms
    - Minimize manual inspection
    - Maximize accuracy
    - Complements case study mode
- **Develop and enhance algorithms within WDSS-II**
  - Storm type algorithm can be trained
    - Examine regional influences
  - Additional user specific algorithms
    - Clusters based on additional fields, incorporating lightning parameters, and calculating higher order parameters

Visualizing a Severe Storm

- **Focus: Cell 73**
  - Severe Wind Report in Cocoa Beach 2011 UTC
  - LDAR source locations for each minute during a one hour period
  - QCReflectivity covering the previous 10 minute period

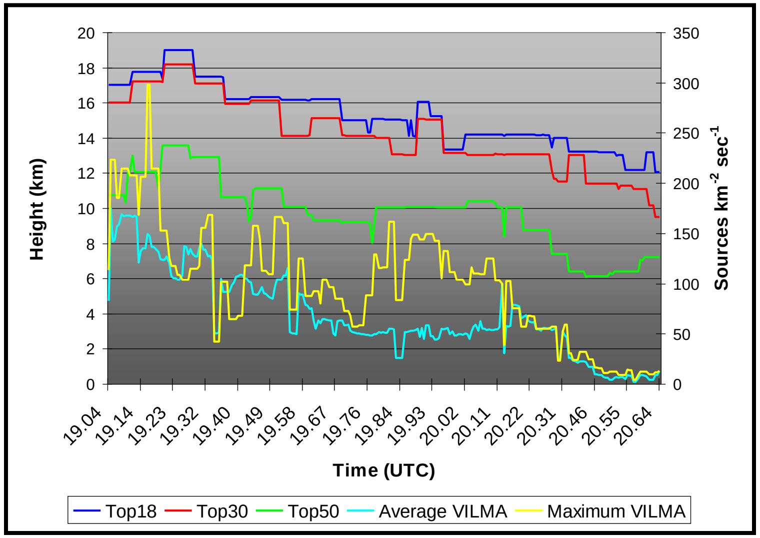
14 August 2005: Cell 73

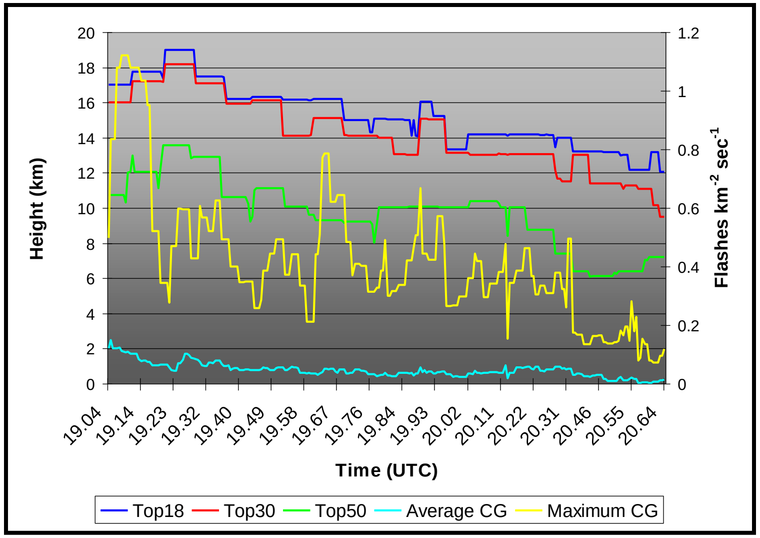


Determining Temporal Variations

- Lightning and radar parameters
  - Relate parameters to storm type
    - Describe lightning variability using radar characteristics
      - Characterize lightning trends with radar parameters, i.e., temporal trends (e.g., “jumps”) and spatial trends (e.g., “holes”)
    - Describe the variability in radar parameters using lightning data
      - Relate the tendency of radar characteristics with total lightning rates, trends, and patterns
    - Consider IR cloud-top temperatures
      - Compare with lightning and radar
      - Cluster entire convective region

14 August 2005: Cell 73

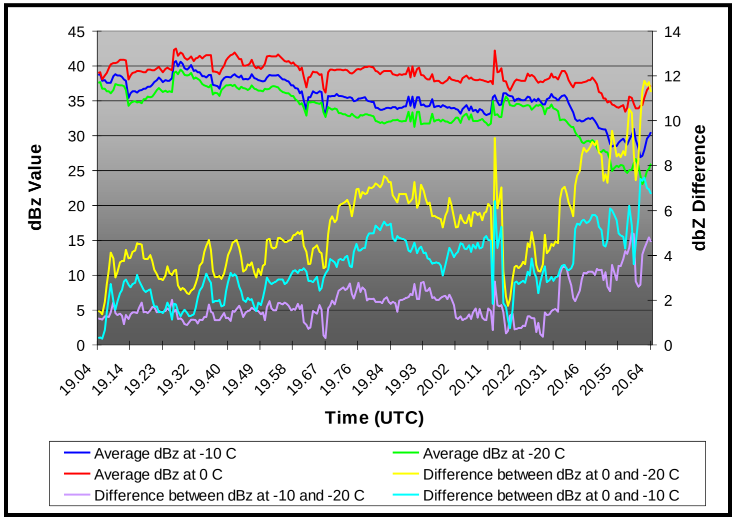


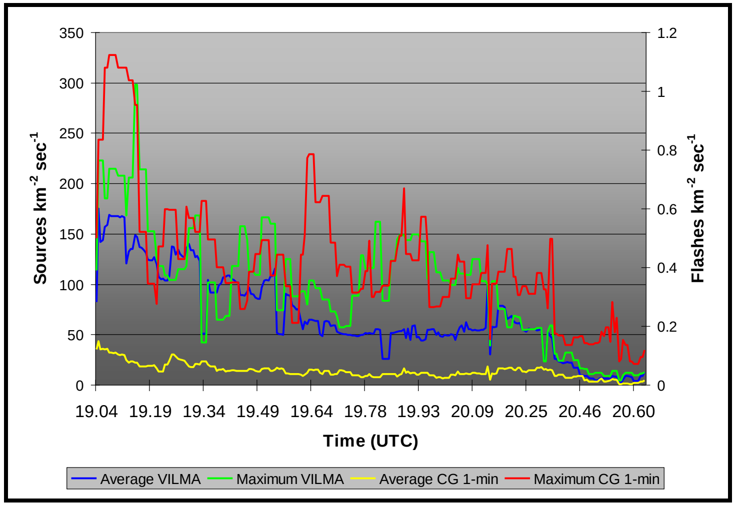


Examine Different Regions of Storms

- **Define regions of the storm**
  - The core, periphery, anvil, and stratiform regions of the storm
    - **Evaluate various parameters to define/cluster these regions**
      - (e.g., VIL, maximum reflectivity, cloud-top temperatures)
    - **Determine relationships between these regions**
      - Differences in areal coverage
      - Describe overall tendencies and their relation to the storm's life cycle
    - **Examine flash source and extent**
  - Link with near-storm environment information to determine the evolution of parameters within these regions and their relation to severe weather

14 August 2005: Cell 73



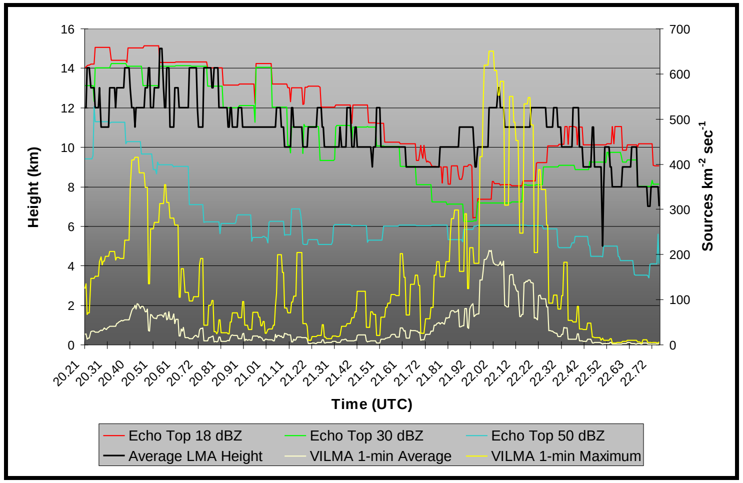


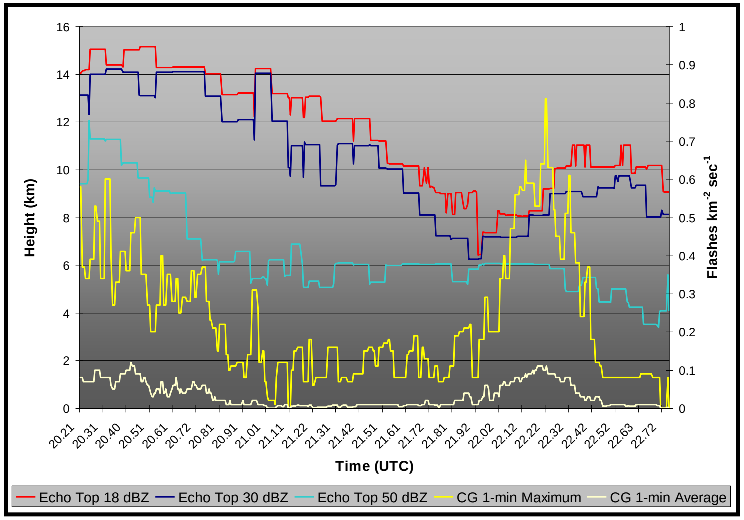
Desirable Attributes

- Modularity is key (Lang 2008)
  - Our scheme must be applicable to different geographical regions
  - Provide a framework that allows for continuing improvements
    - New technology
    - Additional knowledge
  - Use currently available parameters to make most accurate determination
    - If a data source is missing, leverage the remaining data to assist the warning decision process
    - Level of confidence will be affected

13 June 2007: Cell 253

Tracks directly over the radar during peak lightning production



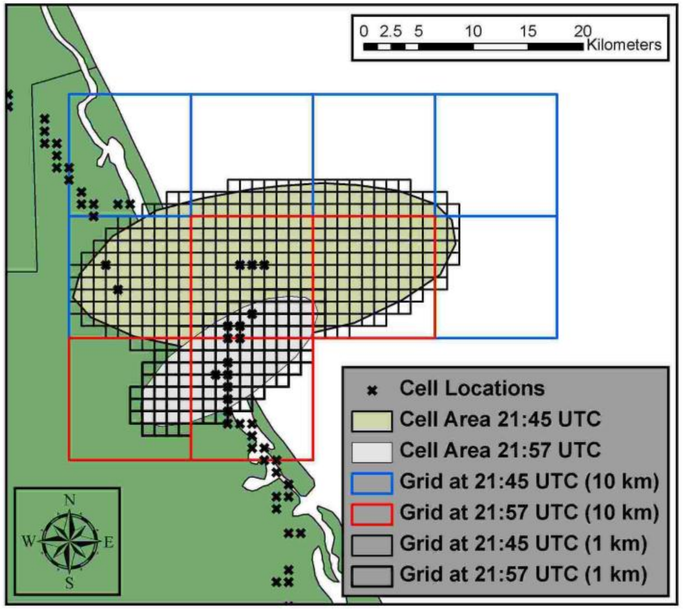


Develop New Storm Intensity Algorithms

- Statistical Approach: Utilize Regression Techniques
  - **Select the optimum parameters**
    - Parameter possibilities are infinite
    - Determine best relationships and combinations
    - Larger statistical sample than individual case studies
  - **Relate chosen parameters to storm type**
    - Trends of lightning and radar parameters
    - Examine three dimensional development
    - Examine many severe and non-severe storms
  - **Develop probabilistic forecasts of severity**
    - Improve the lead time for warning severe events
    - Incorporate total lightning to quantify storm severity at increasing distance from the radar

How does this Relate to GOES-R GLM?

- Spatial Aspects
  - Calculate radar and lightning parameters within active 10×10 km GLM grid cells
  - Compare with finer scale features (or clusters)
  - Examine spatial relationships and trends



- Temporal Aspects
  - Total flash rates every minute
  - Early detection of cells not yet observed by the radar due to beam blockage and/or long distances from radar

- GLM Applicability – Risk Reduction
  - Determine the suitability of GLM data in its native form for assessing storm severity
  - Develop modifications to maximize the benefits of utilizing GLM data

Overriding Theme

- Focus on the decision support process, eventually package for dissemination to NWS WFOs.
- Help insure that NWS is currently using lightning data to best advantage when assessing severe weather events.
- Help insure that the NWS is fully prepared to utilize the upcoming GLM data to aid in determining severe weather potential.